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Packet Radio Temporary Note #17

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THE ALOHA RADIO MODULATION SCHEME

This note has been generated in order to provide infoimation on the RF modulation technique presently in use on the University of Hawaii ALOHA radio computer communication network. This note is only tutorial, intended to provide the reader with some insight into how the present approach came about, a general description of the hardware design, and a possible future evolution of the present design.

BACKGROUND OF DEVELOPMENT

Expediency best describes the development of our present design. In order to implement a hardware configuration as soon as possible, we looked for off-the-shelf equipment which could be interfaced with a minimum of effort and cost. Since our two assigned frequencies were in the 406-420 MHZ government radio band, with channel bandwidths of 100 KHZ each, the choice of a radio quickly narrowed down to a Lenkurt FM radio designed for common-carrier point-to-point use. All other transceivers in this frequency range were for single voice channel use only and did not have receivers of sufficient bandwidth to fully utilize the allocated 100 KHZ bandwidths. The Lenkurt transmitter, like many FM transmitters, generates FM synthetically by integrating the baseband input signal and then applying the integrated signal to a phase modulator. Since we desired to avoid modifying the transceiver in order to generate and receive a truly FM signal, a subcarrier approach was selected. This seemed quite feasible since the required bit rate of 24 KBS was low enough to fit the modulation spectrum into the baseband passband of the transceiver. A search was made for a commercial modem which would operate at our desired bit rate and also provide a rapid synchronization capability for packet acquisition. The result was the selection of the ASTROCOM Series 400 modem which uses binary differential-phase-shift-keying of a 24 KHZ carrier. Thus, a DPSK/FM system was evolved which is presently in use. Although the system is sub-optimal in terms of bandwidth utilization, it does allow ease of interfacing off-the-shelf hardware. Should

THE ALOHA SYSTEM data rate be increased in the future to a higher bit rate in order to more fully utilize the channel bandwidth, then the present modulation scheme will probably be changed.

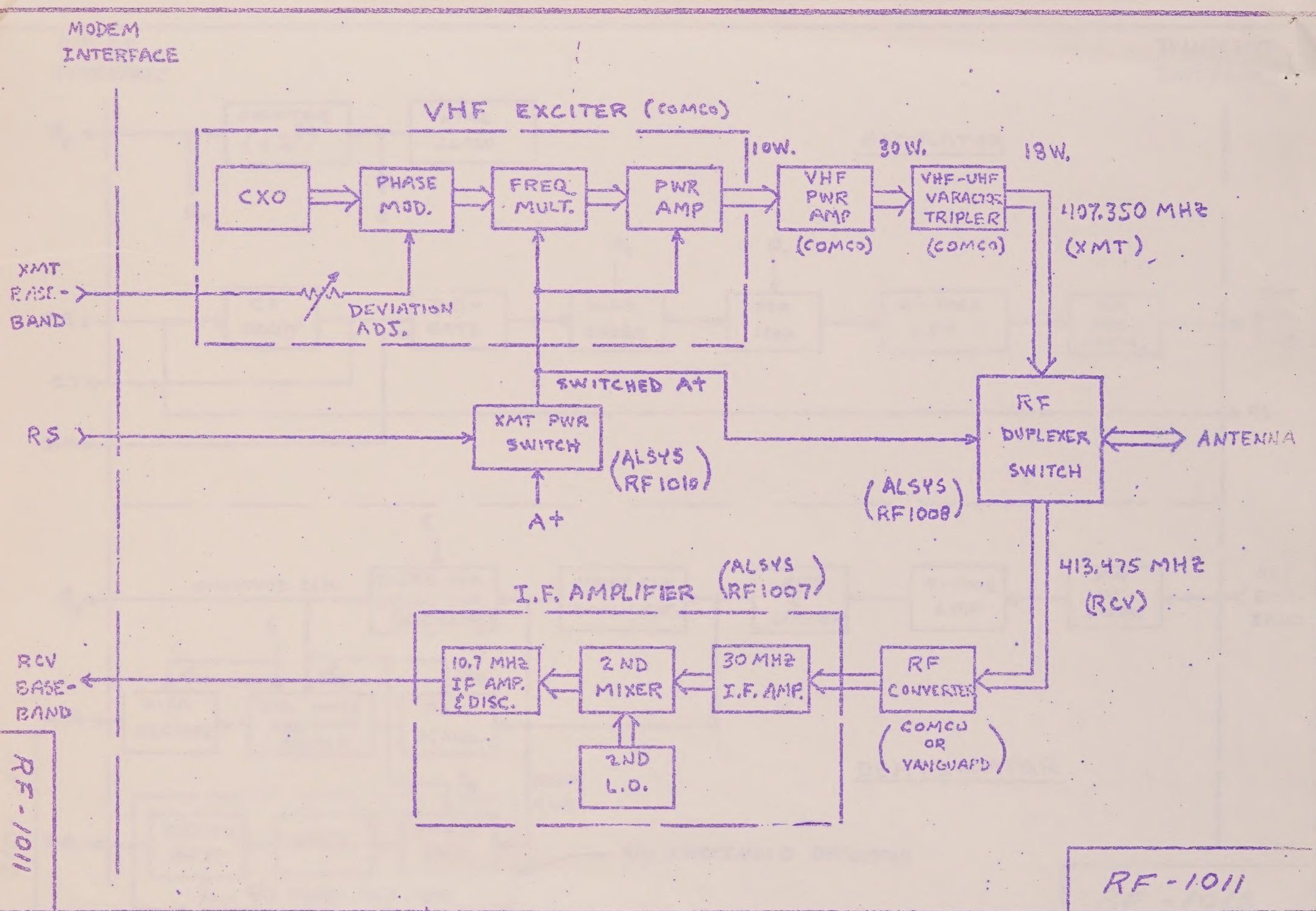
HARDWARE DESIGN

As described above, the radio portion of THE ALOHA SYSTEM was first implemented using off-the-shelf hardware. However, each installation was large and cumbersome, and it was felt that future units could be made much more compact through some hardware design effort. This effort resulted in THE ALOHA SYSTEM's Terminal Control Unit (TCU) which forms the interface between a user's terminal device and the ALOHA channel. For the radio portion of the TCU, transmitter and receiver components were purchased from COMCO, a manufacturer of mobile radio equipment. The RF Duplexer Switch was fabricated by ALOHA using a high-speed microcircuit manufactured by Motorola. ALOHA also designed and built the receiver IF Amplifier-Discriminator assembly to meet its own unique requirements. A block diagram of the TCU radio is shown in the attached drawing, number RF-1011. A modem was also designed and fabricated by ALOHA for use in the TCU. A block diagram of this modem is shown in the attached drawing RF-1012. DPSK modulation is employed to ensure compatibility with the commercial units in use. Matched filtering was employed in this design so that the modem could maintain low error rates for S/N ratios much lower than the commercial units could handle. Since the incoming carrier at a TCU is received continuously, the modem was not designed for rapid acquisition. The narrow bandwidth of the phase-locked-loop clock recovery circuit allows considerable jitter reduction of the recovered clock. The coherency of the subcarrier signal (crystal clock source) is used to provide a low false-alarm rate carrier-on flag to the data buffer. The modem has been found to operate reasonably well--an error rate curve is attached as Fig. 1. Although the measurement was performed at 9.6 KBS, it is believed that the performance is about the same at 24 KBS. Actually, overall error rate performance is controlled by the FM threshold of the radio receiver. Since a modulation index of about one is used, in addition to pre-emphasis, the baseband S/N ratio is relatively high for the modem at the point that the FM receiver reaches its threshold. The baseband S/N ratio then drops much more rapidly with decreasing RF carrier power so that a very sharp FM threshold effect is experienced. Another effect of the DPSK/FM system is the low capture ratio experienced. Although accurate measurements have not yet

been made, lab experience indicates the capture ratio is in the order of one dB.

FUTURE DEVELOPMENT

The present scheme will not be changed, unless future requirements so dictate. The radios and modems can be modified to provide an FSK modulation scheme, allowing the bit rate to be increased to 50 KBS. More sophisticated modulation methods, such as quadra-phase-shift-keying, will require extensive redesign, which is not anticipated. Future efforts will be directed toward radio range studies of the operating system and collection of radio channel data. Some hardware effort will be directed toward modifying the present TCU modem design for rapid burst acquisition. This modem will be needed in the proposed packet radio repeater and in TCU's operating off of the repeater.



ALOHA System Project, U. of H.
System TCU TRANSCEIVER Sub-system BLOCK DIAGRAM
Name D. Wax
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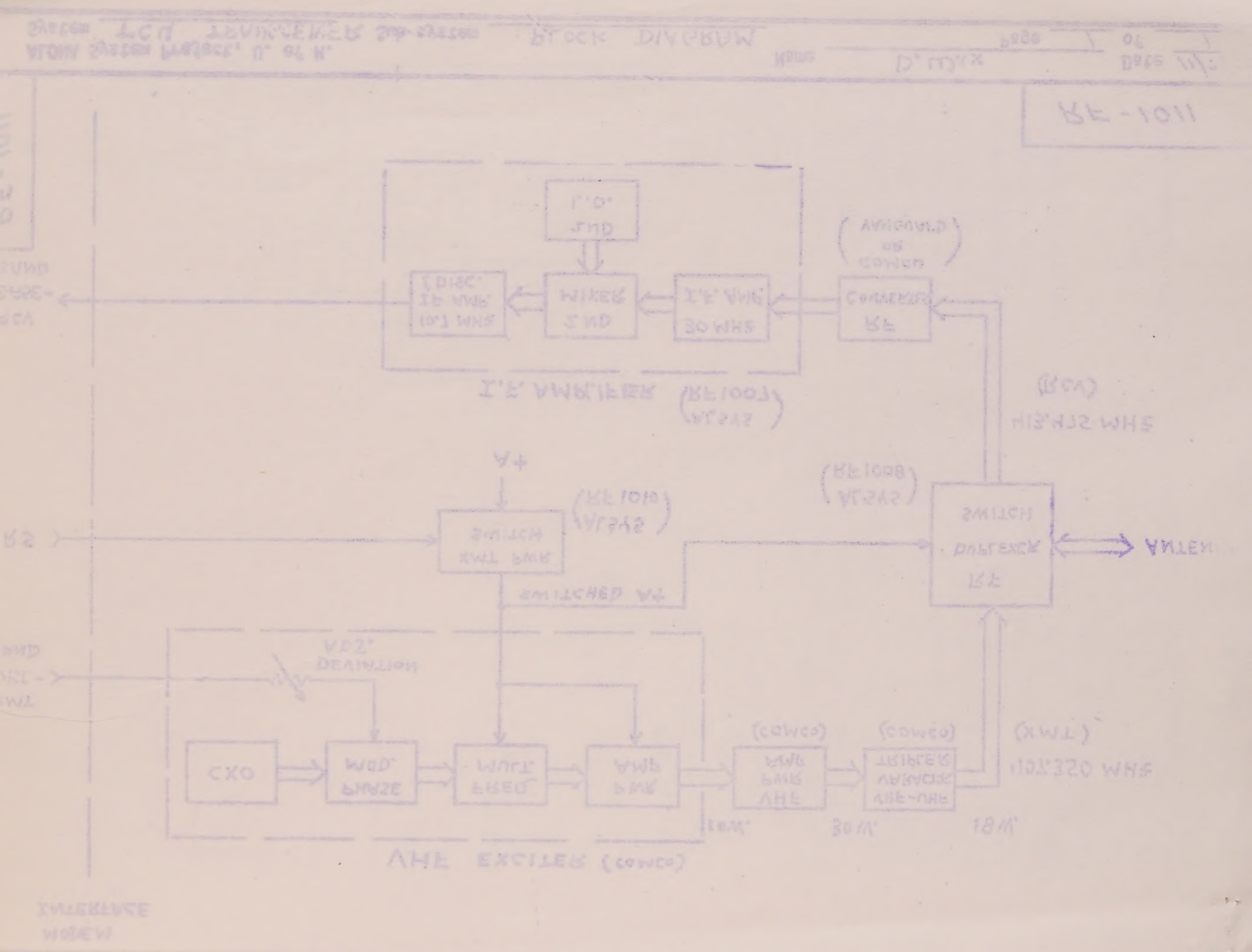
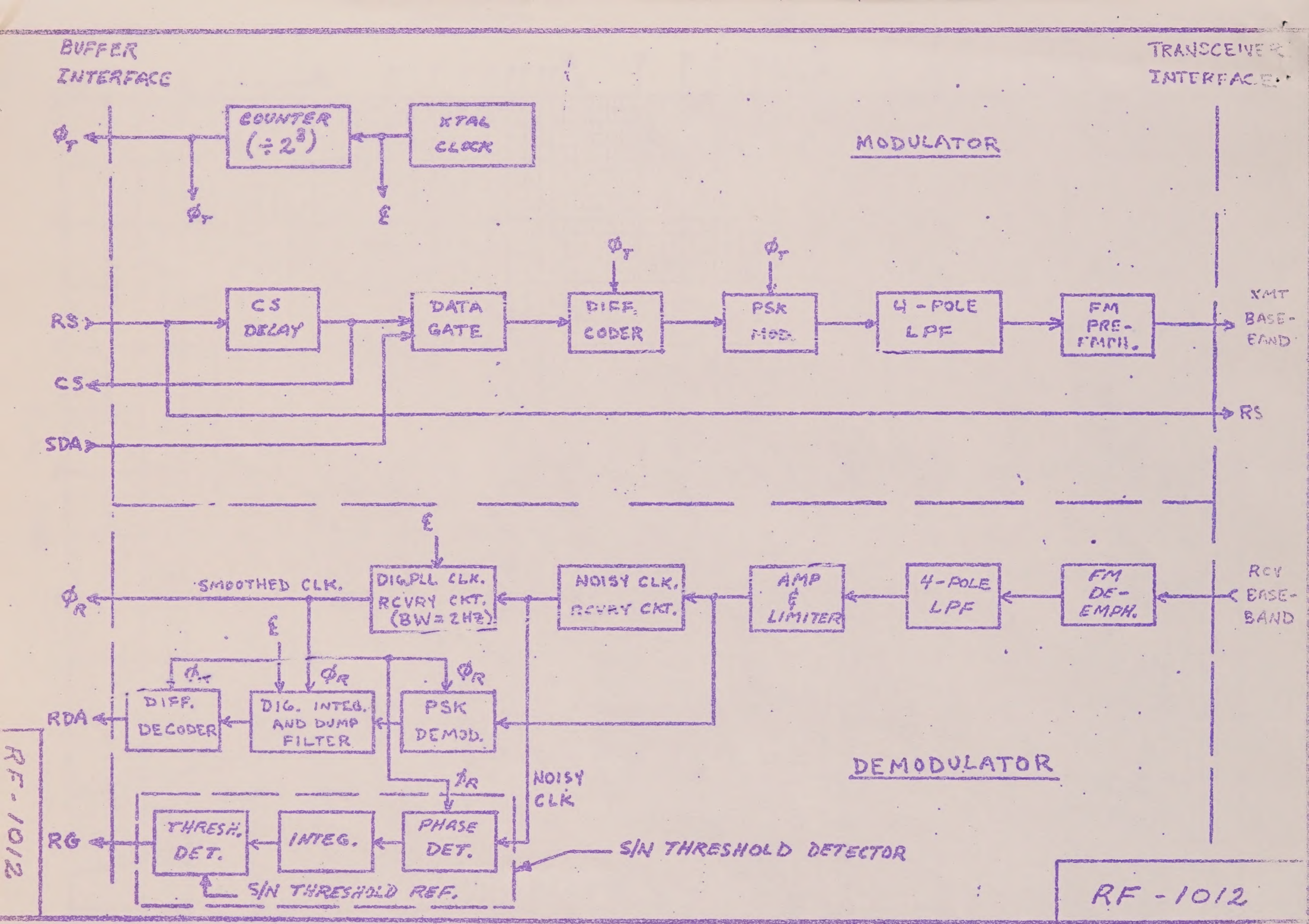
Date 11/7/72


RF-1011
BLOCK DIAGRAM
L.E. AMPLIFIER (RF1003)
(AVAILABLE ON COMBO)
COMBINER RF
30 WHS
L.E. AMP
MIXER
SND
L.O.
SWITCH (RF1008)
SWITCH (RF1010)
SWITCHED AT
DIPLEXER RF
ANTENNA
VHF EXCITER (COMBO)
CXO
MOD. PHASE
MULT. FREQ
AMP PWR
PWR AMP VHF
ATTENUATOR VHF-UHF
(COMBO)
(COMBO)
(XMT)
10W
30 W
18 W



RF-1012

ALOHA System Project, U. of H.
System TCU MOD.FM Sub-system BLOCK DIAGRAM Name D. Wax Date 11/2/78
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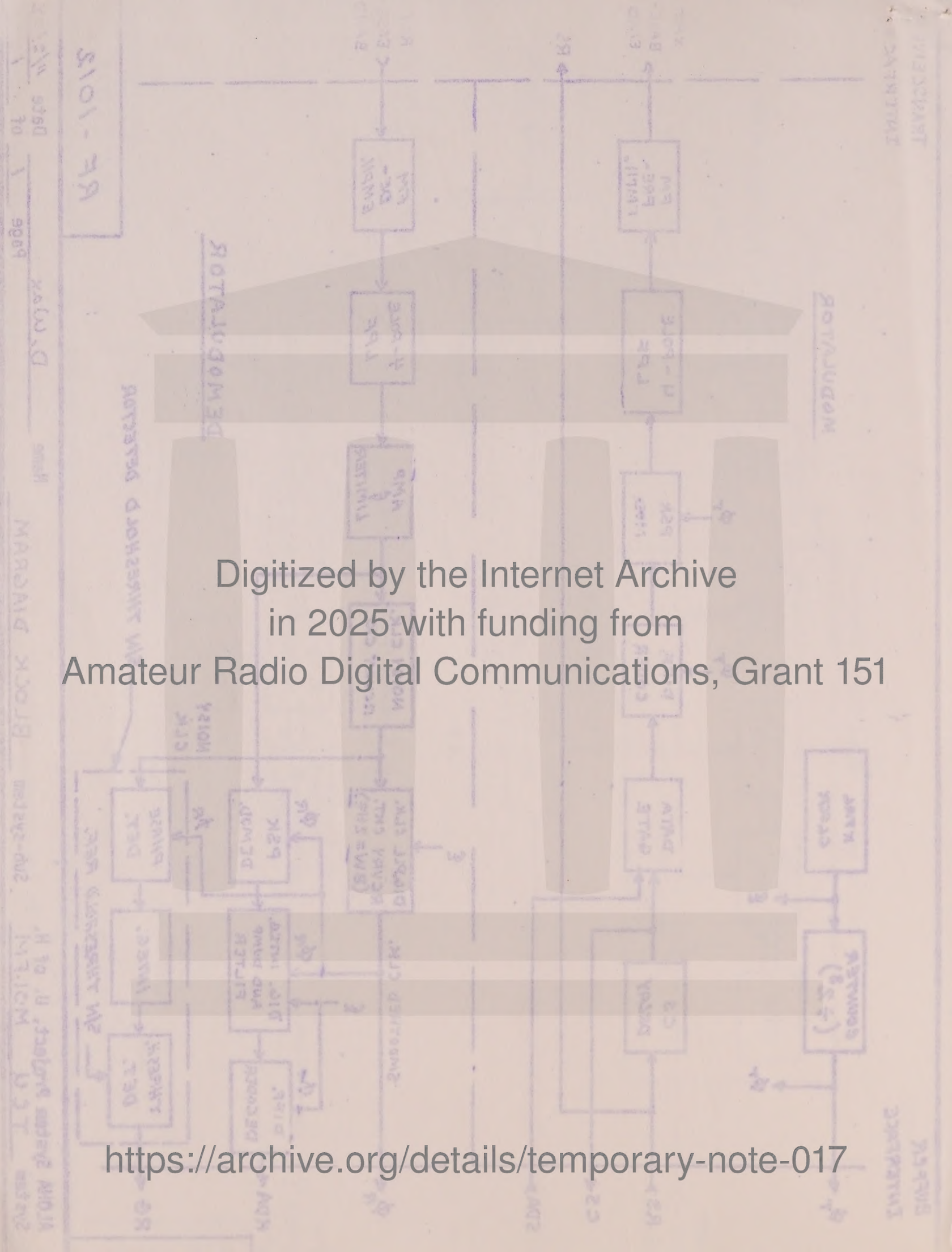

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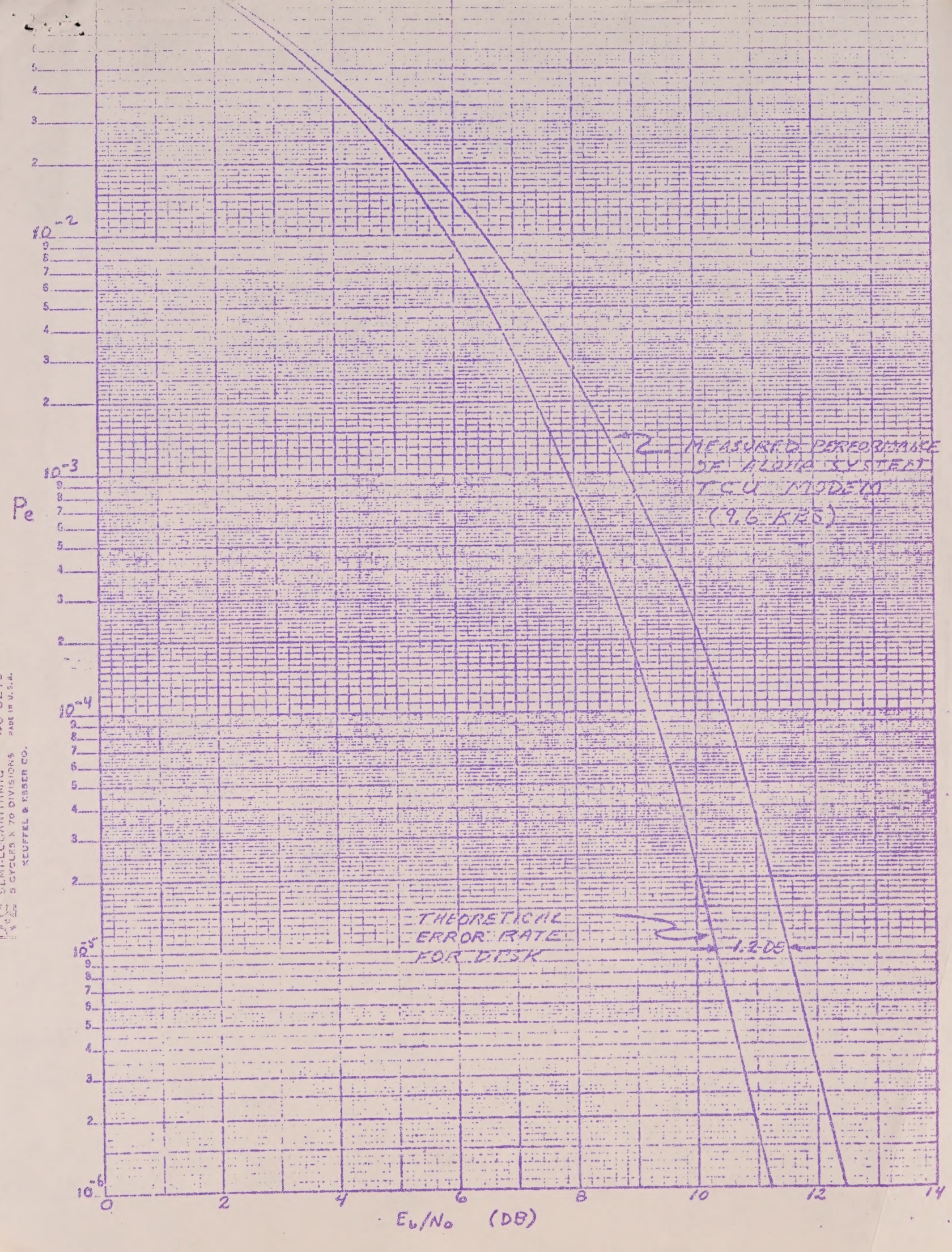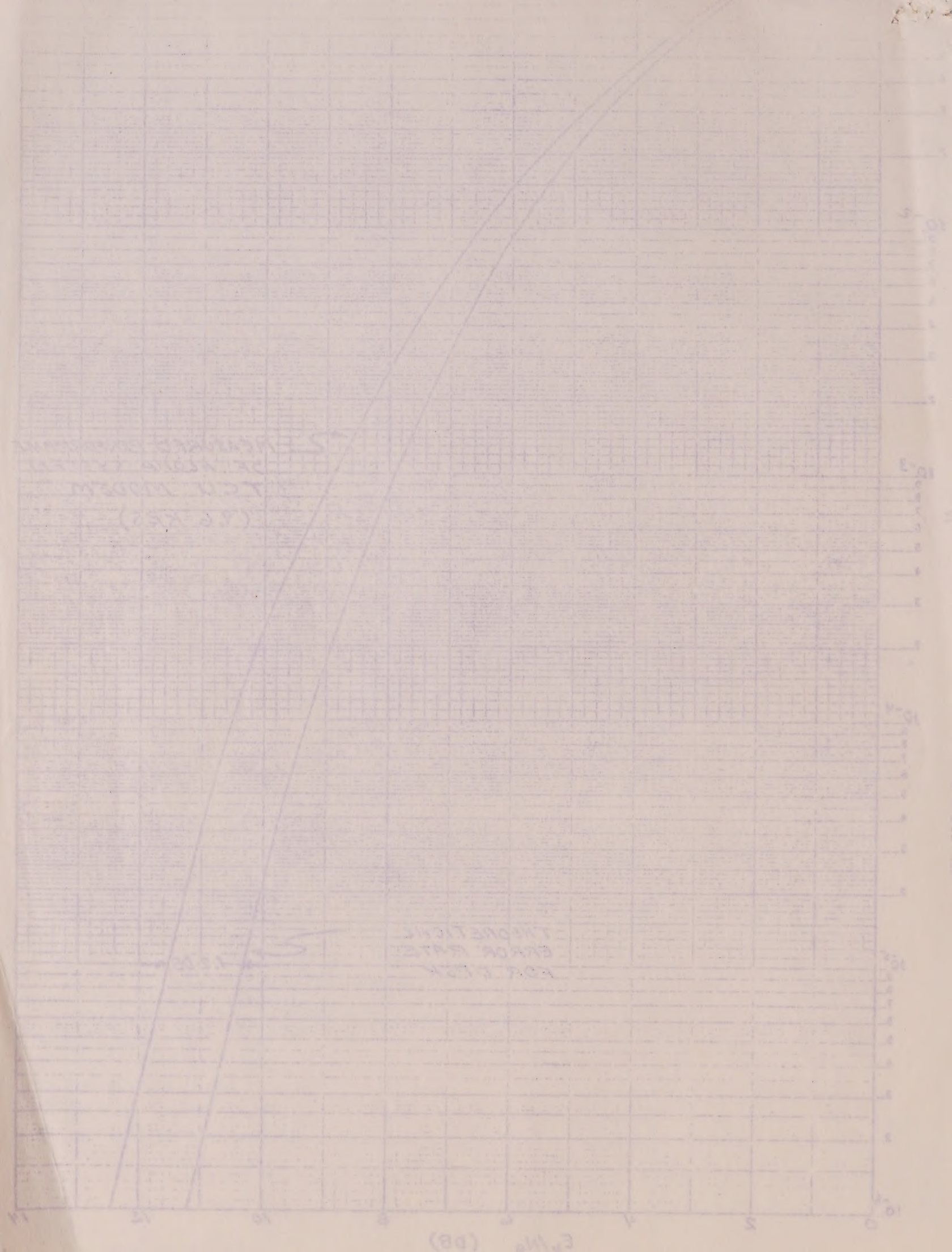
Pe
E_b/N_o (DB)
2 - MEASURED PERFORMANCE OF ALOHA SYSTEM TCU MODEM (9.6 KBS)
THEORETICAL ERROR RATE FOR DPSK
1.2-05
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
2
4
6
8
10
12
14